Private Sector Career Opportunities for Physicists at a time of Industrial Innovation Disruptions

Thierry Valet

MAINZ & SPICE Center

PhD SPINCAT Workshop

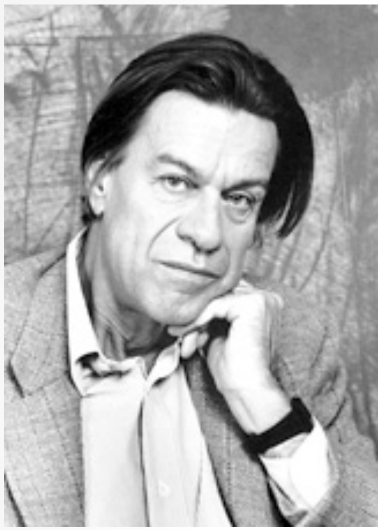
August 18, 2016

Private sector opportunities for physicists ???

(Somewhat) more seriously …

- The majority of PhD graduates do not end up pursuing an academic career
- Major industries (micro-electronics, car, energy…) are at key junctures which cry for MORE / FASTER / BETTER innovations
- The pressure of economic relevance, of practical considerations, are not necessarily impediment to creativity, scientific sophistication…to the contrary !
- The world is flat now…smaller, faster…less predictable…
- (One could hope) that a PhD program is a training BY the research, not just a training TO the research

Who am I to talk about that anyway…



Pierre-Gilles de Gennes
(1932 - 2007)
ESPCI Paris Tech Director, 1976-2002
Nobel Prize in Physics 1991

Jacques Friedel
(1921 - 2014)
Laboratoire de Physique des Solides
1959-1990
French, US and British Academy of Sciences

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

MATERIALS SCIENCE IN MAINZ

Present **Johanes Gütenberg University** Mainz, GERMANY
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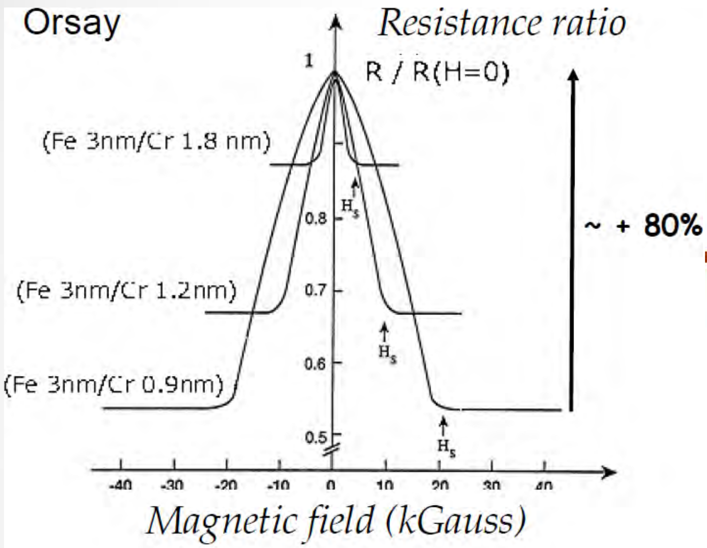
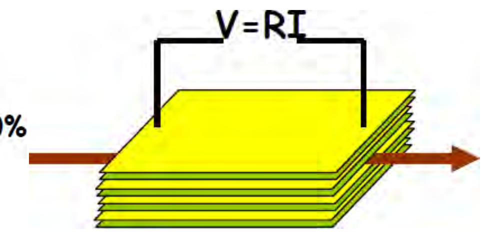
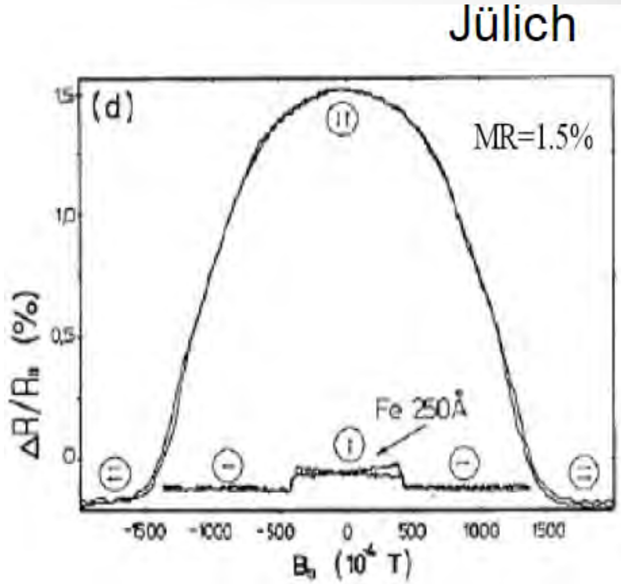
The Discovery of Giant Magneto-Resistance





Current in Plane (CIP) GMR

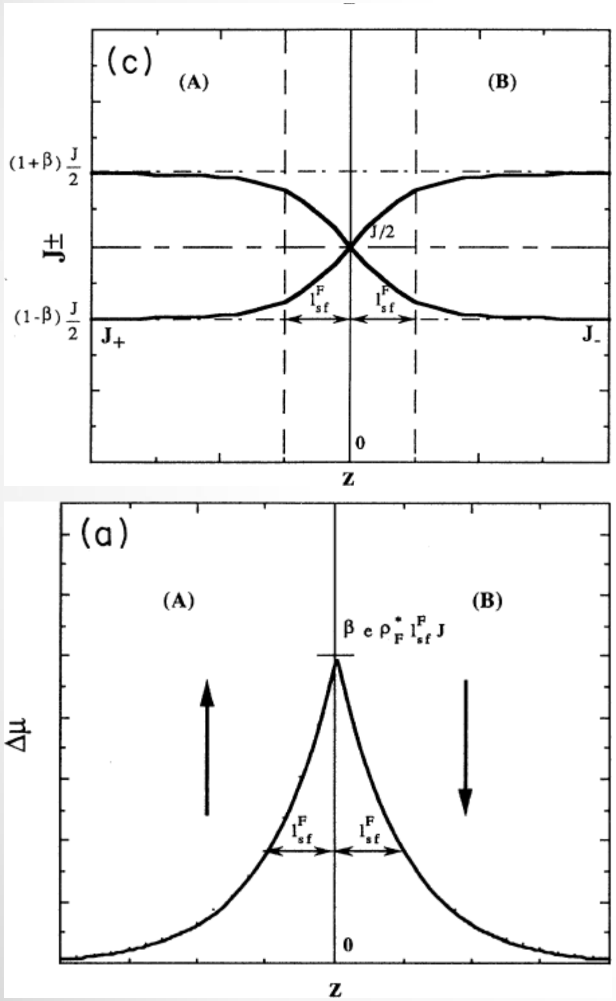


Orsay (Fe/Cr multilayers) / Jülich (Fe/Cr/Fe trilayers) 1988-1989

P. Grünberg and A. Fert
Nobel Prize in Physics 2007

“spintronics” is born…

Valet-Fert Theory of CPP GMR

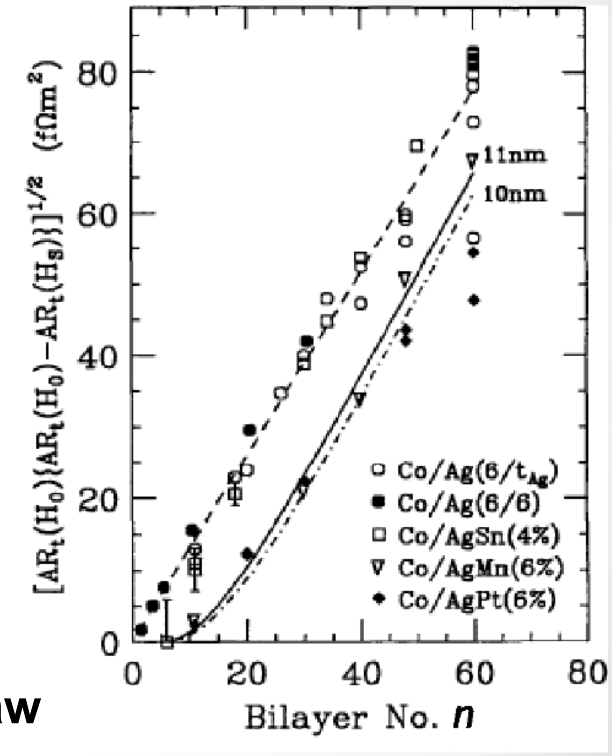


$$\frac{e}{\sigma_s}\frac{\partial J_s}{\partial z} = \frac{\bar{\mu}_s - \bar{\mu}_{-s}}{l_s^2},$$

$$J_s = \frac{\sigma_s}{e}\frac{\partial \bar{\mu}_s}{\partial z}$$

Spin (non conserving) generalization of Ohm's law

Valet and Fert (1993)



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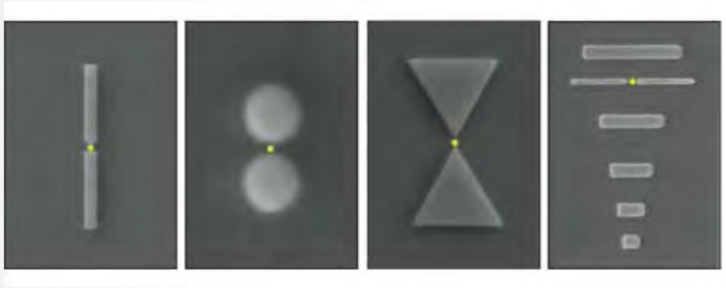
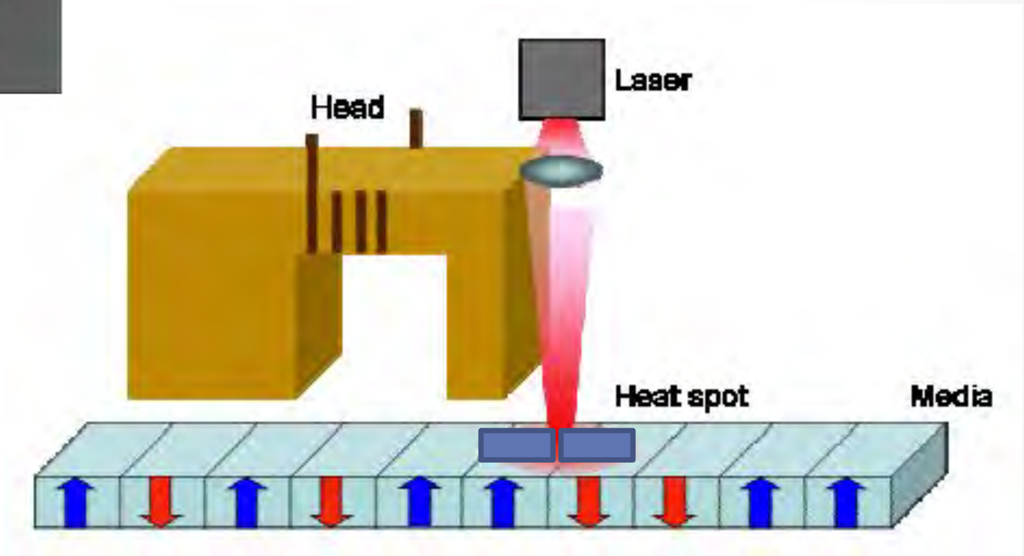
HDD - Heat Assisted Magnetic Recording

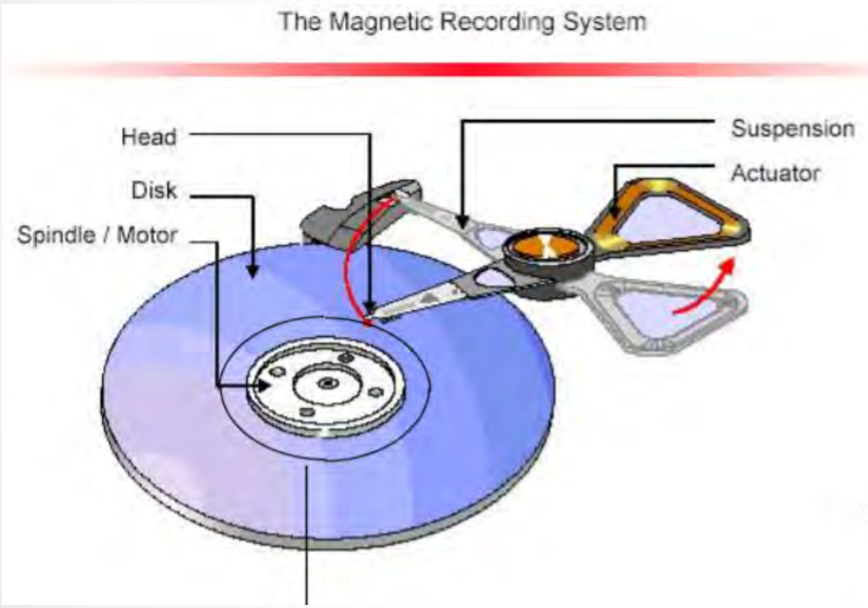


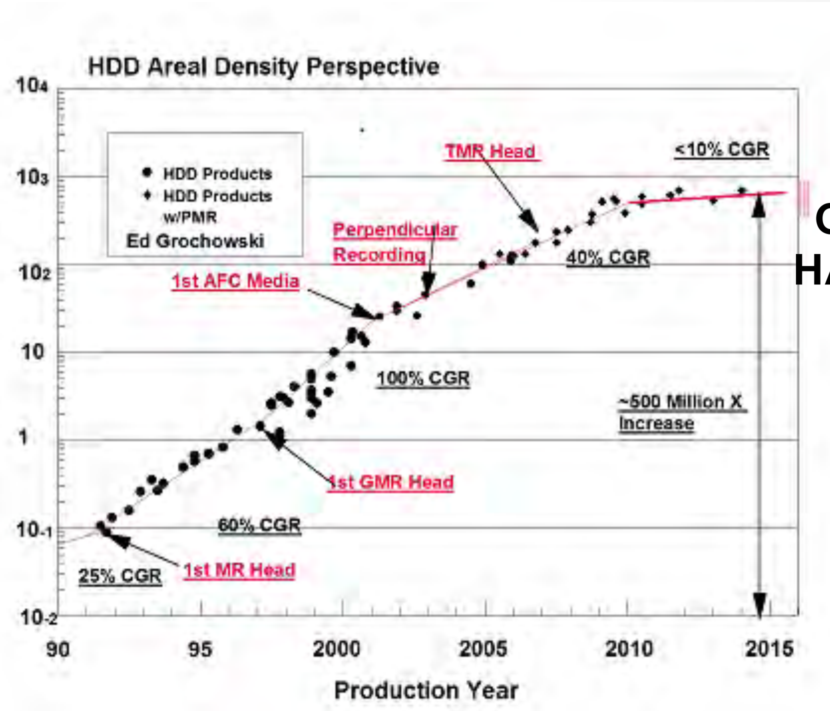
Optical Antennas



T. Valet and O. Fallou, USPTO 6,304,522 (2001)
T. W. Mc Daniel and T. Valet, USPTO 6,714,370 (2004)

Data Storage - Hard Disk Drives





CPP
GMR(?)
HAMR(?)

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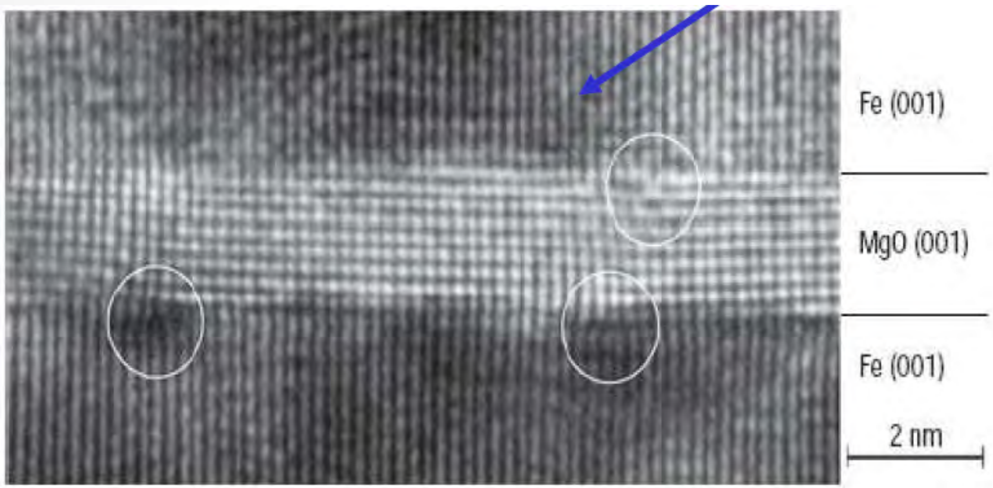
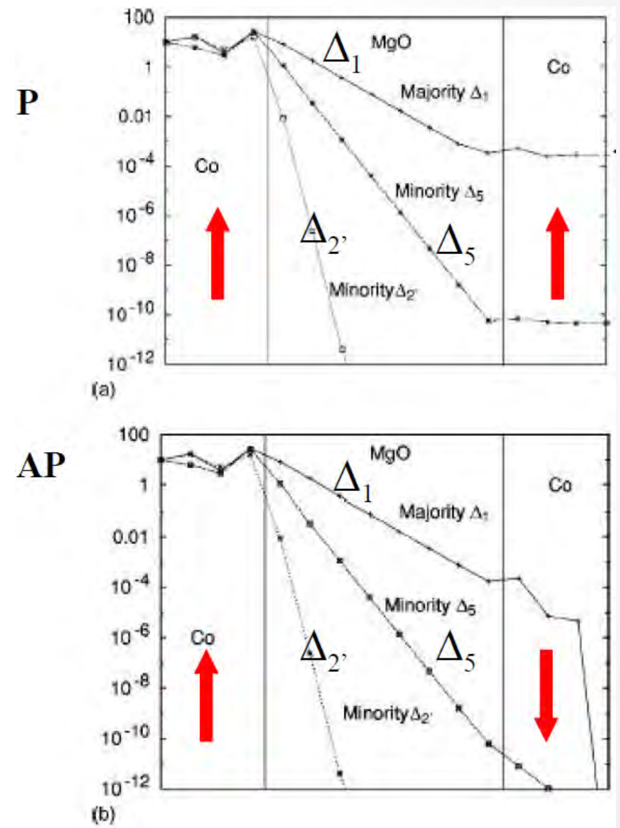
Magnetic Tunnel Junction - TMR

Juliere (1975) LT
Moodera (1995) 30-40 %, RT



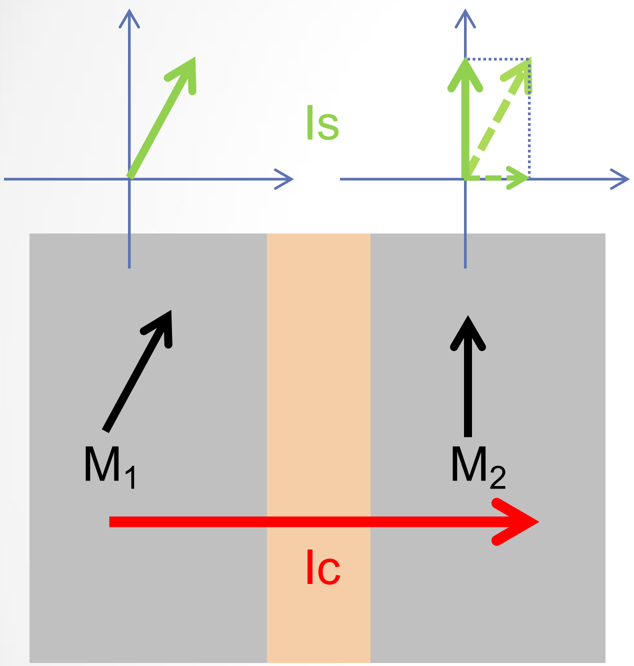
Yuasa et al (2005) Fe/MgO 200 %, RT

Yuasa / Parkin … (2006 …)
CoFeB/MgO 500% and up, RT



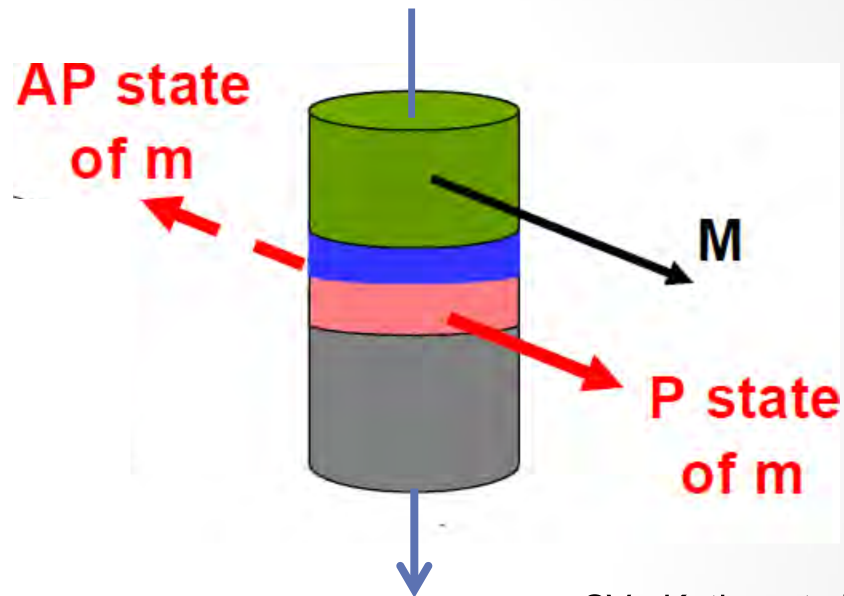
Zhang and Butler (2004)

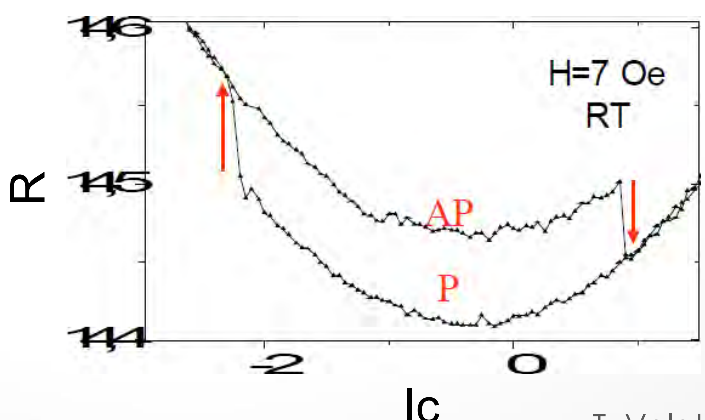
Spin Transfer Torque (STT)



$$\left(\frac{d\mathbf{M}_2}{dt}\right)_{STT} \propto I_c \mathbf{M}_2 \times (\mathbf{M}_1 \times \mathbf{M}_2)$$

Slonczewski (1996)
Berger (1996)

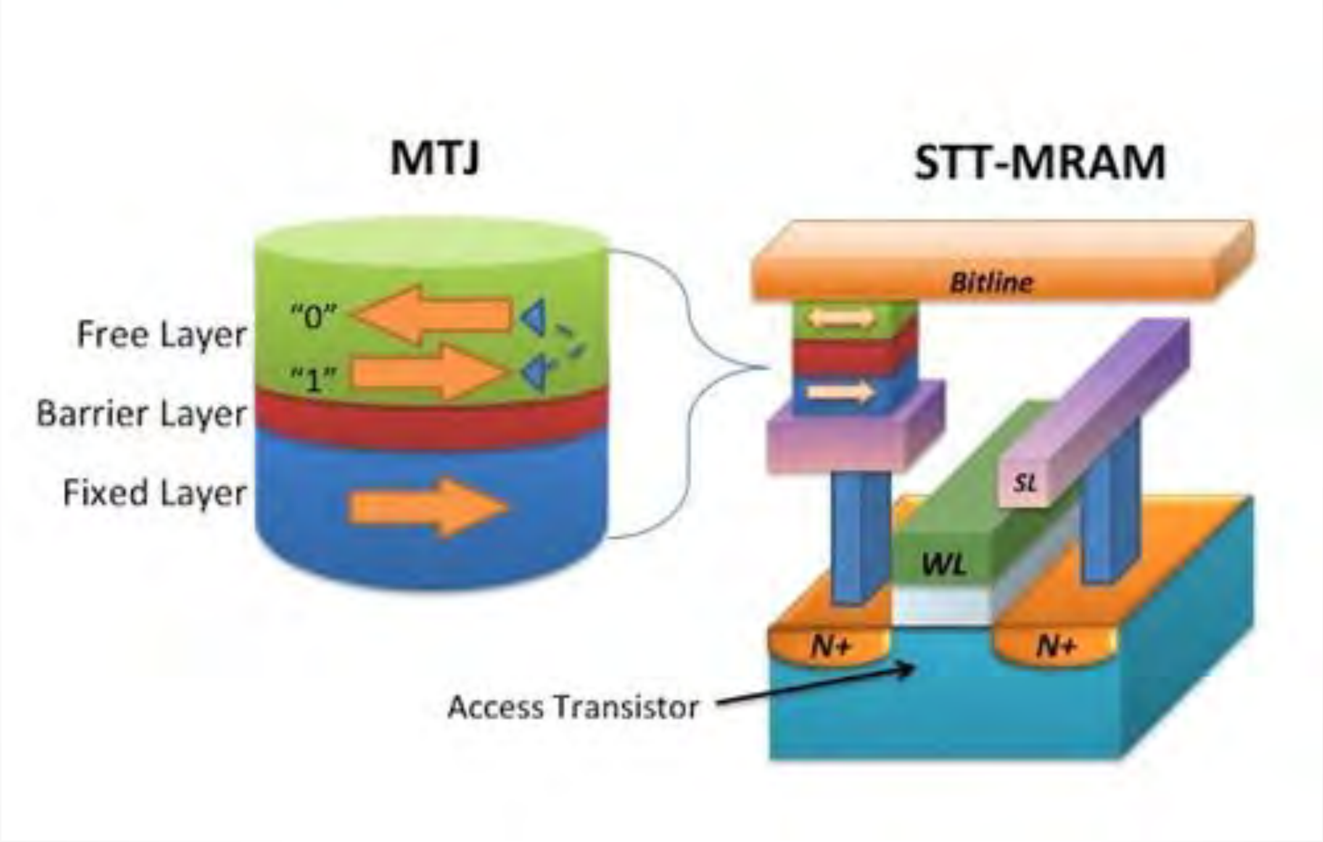




SV : Katine et al (2000)

MTJ : Y. Huai, F. Albert, P. Nguyen, M. Pakala and T. Valet, Appl. Phys. Lett. 84, 3118 (2004)

STT Magnetic Random Access Memory



Major ongoing developments : Samsung, Toshiba, IBM…

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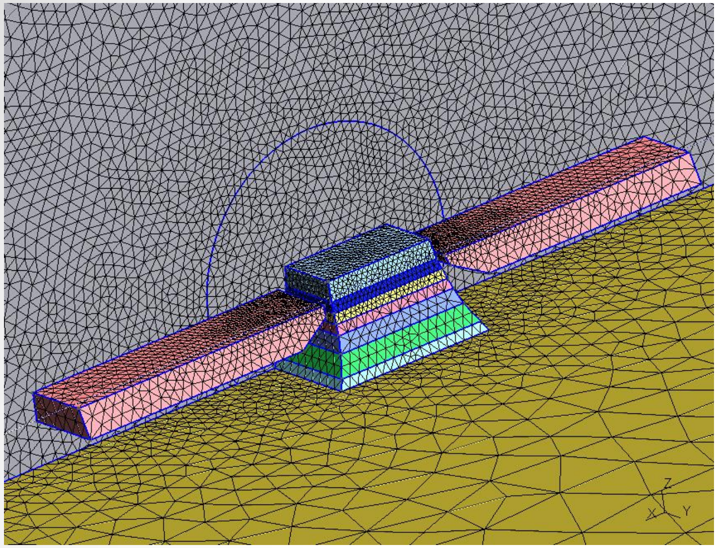
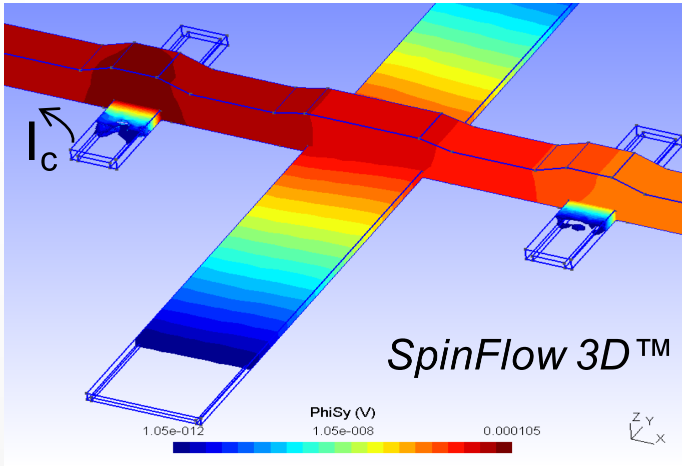
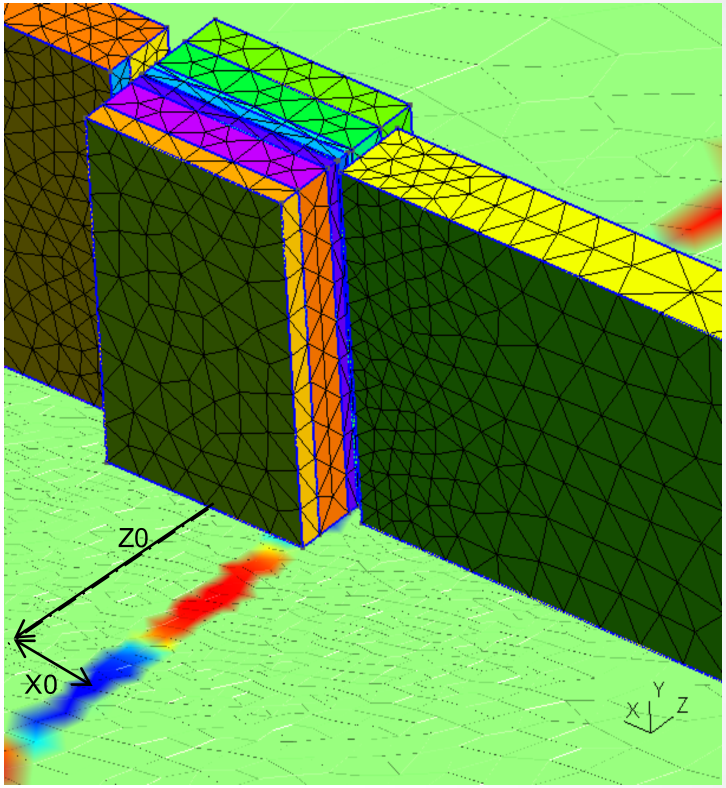
A Comprehensive Simulation Platform for Spintronics





Diffusion of Sy component of the spin potential (accumulation) for $Cu_{99.5}Bi_{0.5}$ case with assumed $l_{sf}[Cu]$ = 1300 nm (1 mA is flowing through the device)



Sensor + Media Coupon Model (Shields are not displayed for clarity)

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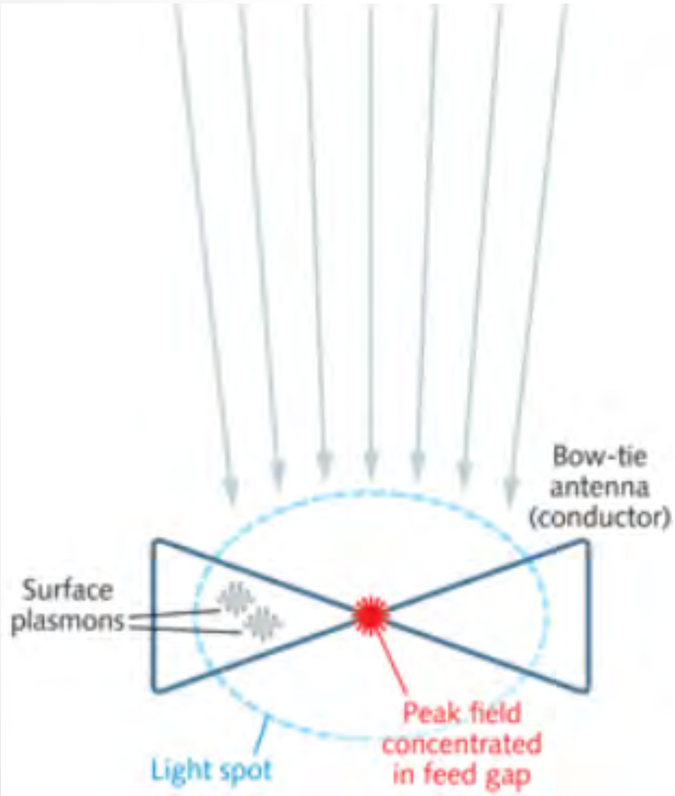
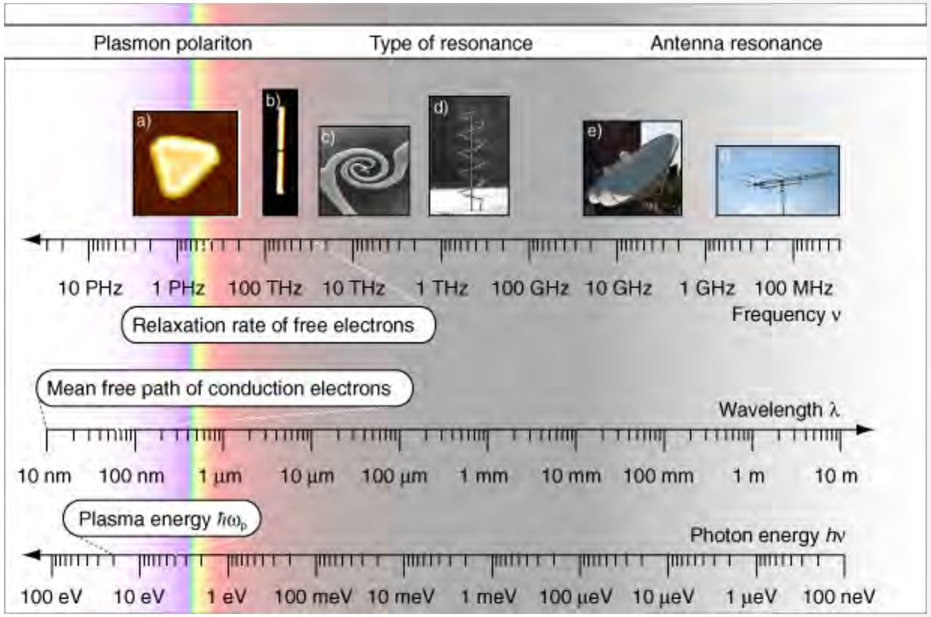
THz and Beyond Conductivity

Metallic Optical Antennas

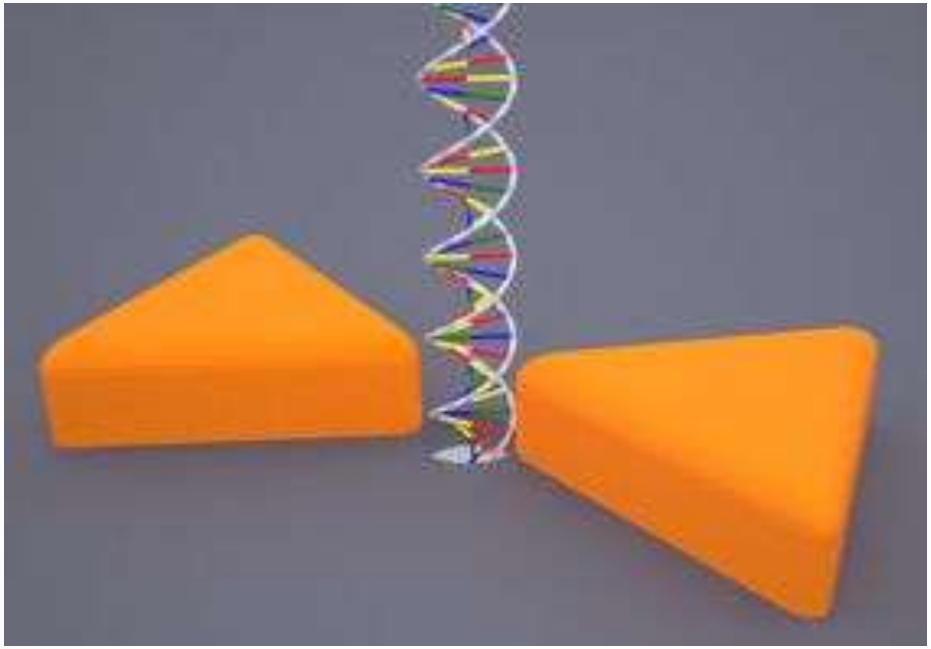




$$\varsigma^2(\omega)\nabla(\nabla.\mathbf{J})+\mathbf{J}=\sigma(\omega)\mathbf{E}$$

Frequency dependent, non local “hydrodynamic” generalization of Ohm’s law - Boardman(1982)
Not quite right…

Nano-Plasmonic for DNA Sequencing ?



Muthukumar et al (2015)

Optimizing such devices will necessitate much improved abilities to model electron flows in metals in the "nano-plasmonic" regime…

What we will cover

- From Bell Labs to Silicon Valley, changing and diverse approaches to the management of innovation
    - Some environment may better suits you than others..
- Numerical simulation in academic settings vs software engineering in corporate environment
    - Training BY research !!!
- A market opportunity, an innovation, a team, some customers, some capital…in that order
    - Startups…

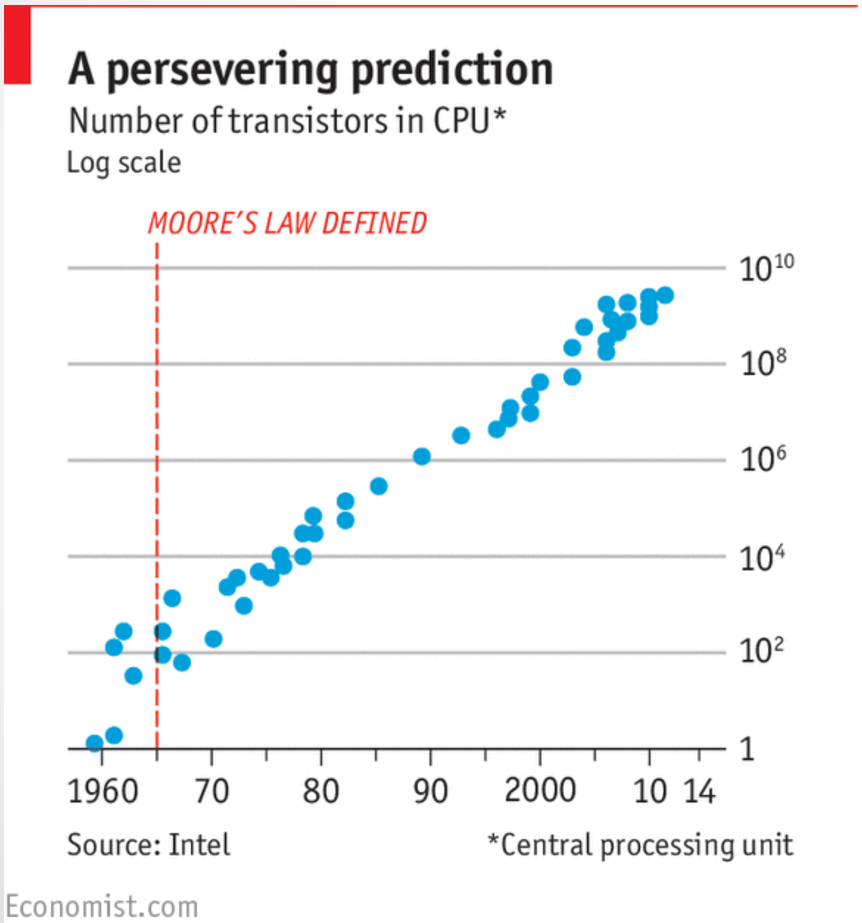
There is plenty of room at the bottom…

Richard Feynman
(1918-1988)
Nobel Prize in Physics 1965

APS Meeting
December 29, 1959

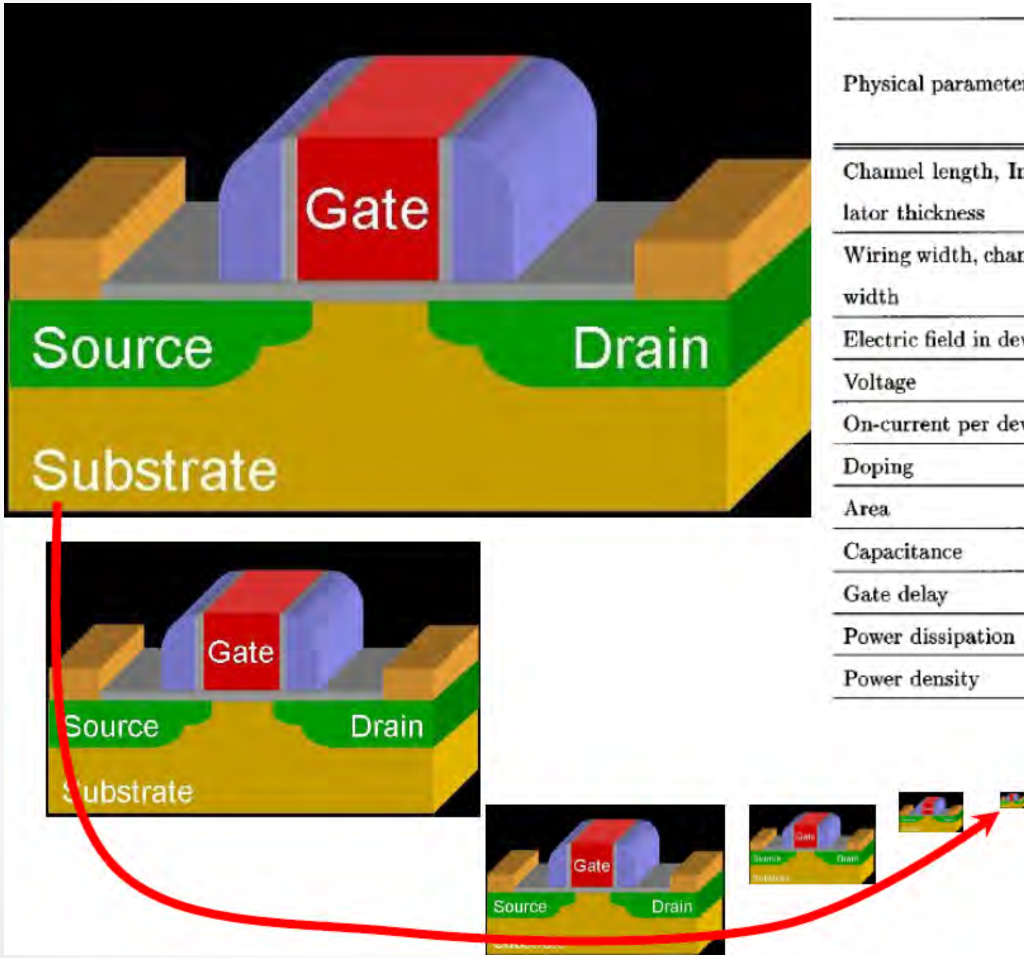
…I do know that computing machines are very large; they fill rooms. Why can't we make them very small, make them of little wires, little elements – and by little, I mean little. For instance, the wires should be 10 or 100 atoms in diameter, and the circuits should be a few thousand angstroms across….

50 Years of Moore's Law



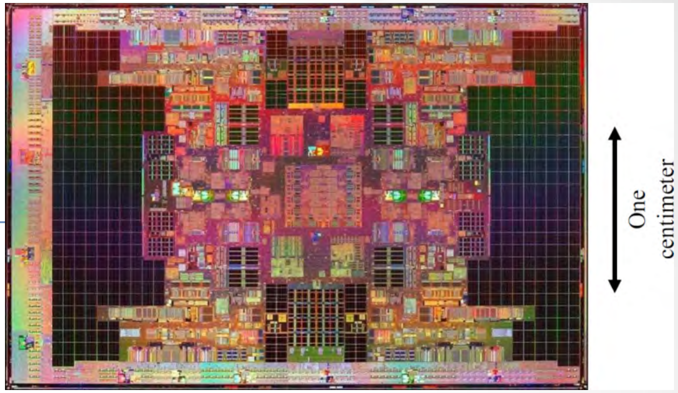
Gordon Moore
Intel's co-founder

Allowed by Physics (so far)

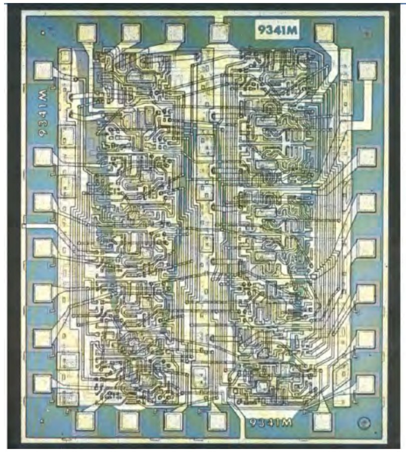


Physical parameter	Constant-Electric Field Scaling Factor	Generalized Scaling Factor	Generalized Selective Scaling Factor
Channel length, Insulator thickness	$1/\alpha$	$1/\alpha$	$1/\alpha_d$
Wiring width, channel width	$1/\alpha$	$1/\alpha$	$1/\alpha_w$
Electric field in device	1	ε	ε
Voltage	$1/\alpha$	ε/α	ε/α_d
On-current per device	$1/\alpha$	ε/α	ε/α_w
Doping	α	$\varepsilon\alpha$	$\varepsilon\alpha_d$
Area	$1/\alpha^2$	$1/\alpha^2$	$1/\alpha_w^2$
Capacitance	$1/\alpha$	$1/\alpha$	$1/\alpha_w$
Gate delay	$1/\alpha$	$1/\alpha$	$1/\alpha_d$
Power dissipation	$1/\alpha^2$	ε^2/α^2	$\varepsilon^2/\alpha_w\alpha_d$
Power density	1	ε^2	$\varepsilon^2\alpha_w/\alpha_d$

Allowed by Physics (so far)



(MOS transistors) 2 Billions Transistors (2012)

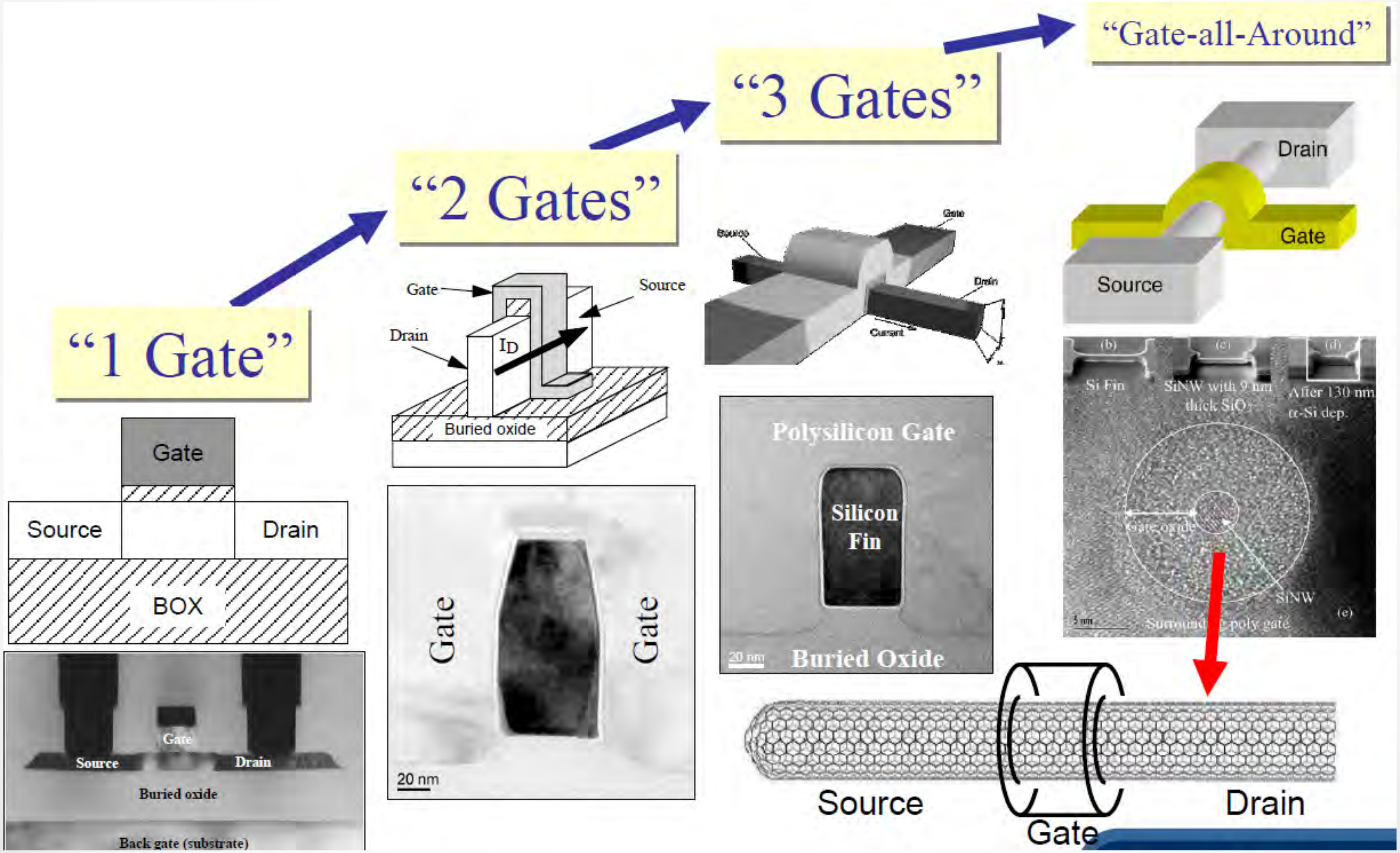


200 Transistors (1969)

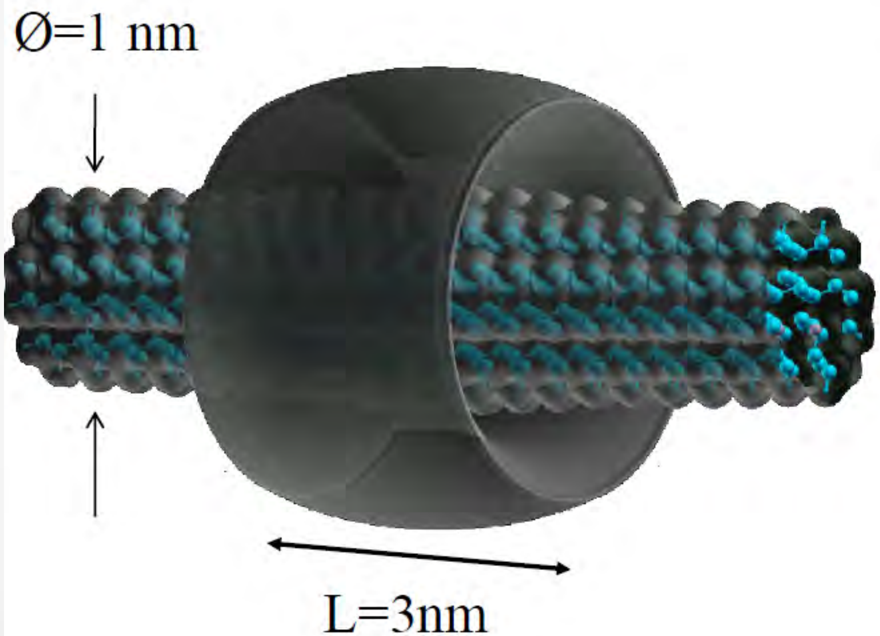
Bardeen, Brattain and Shockley (1947)

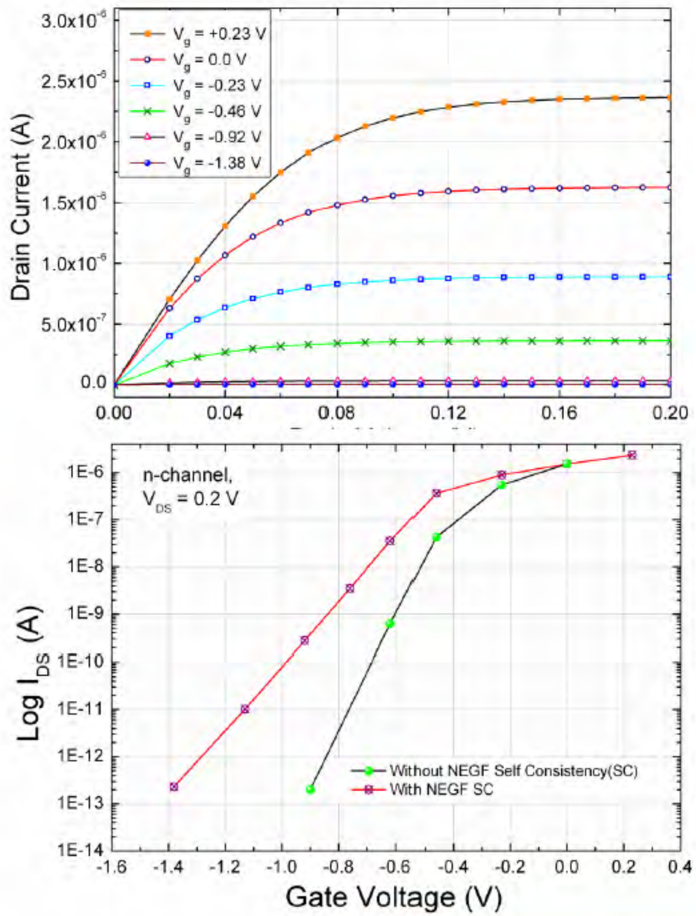
(point-contact transistor)

Allowed by Physics (so far)

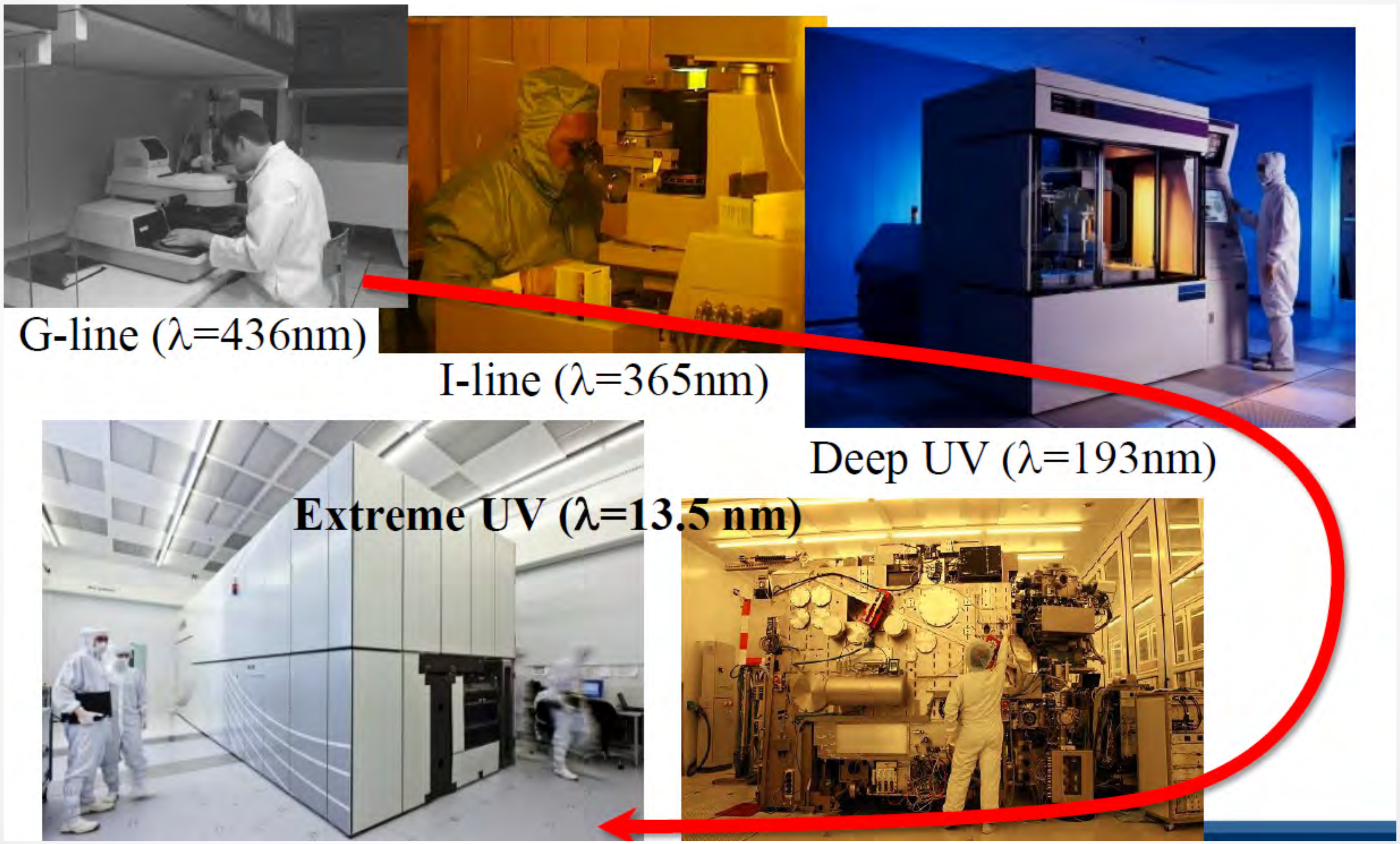


How small can it be ?





Ultimately Fueled and Limited by Economics



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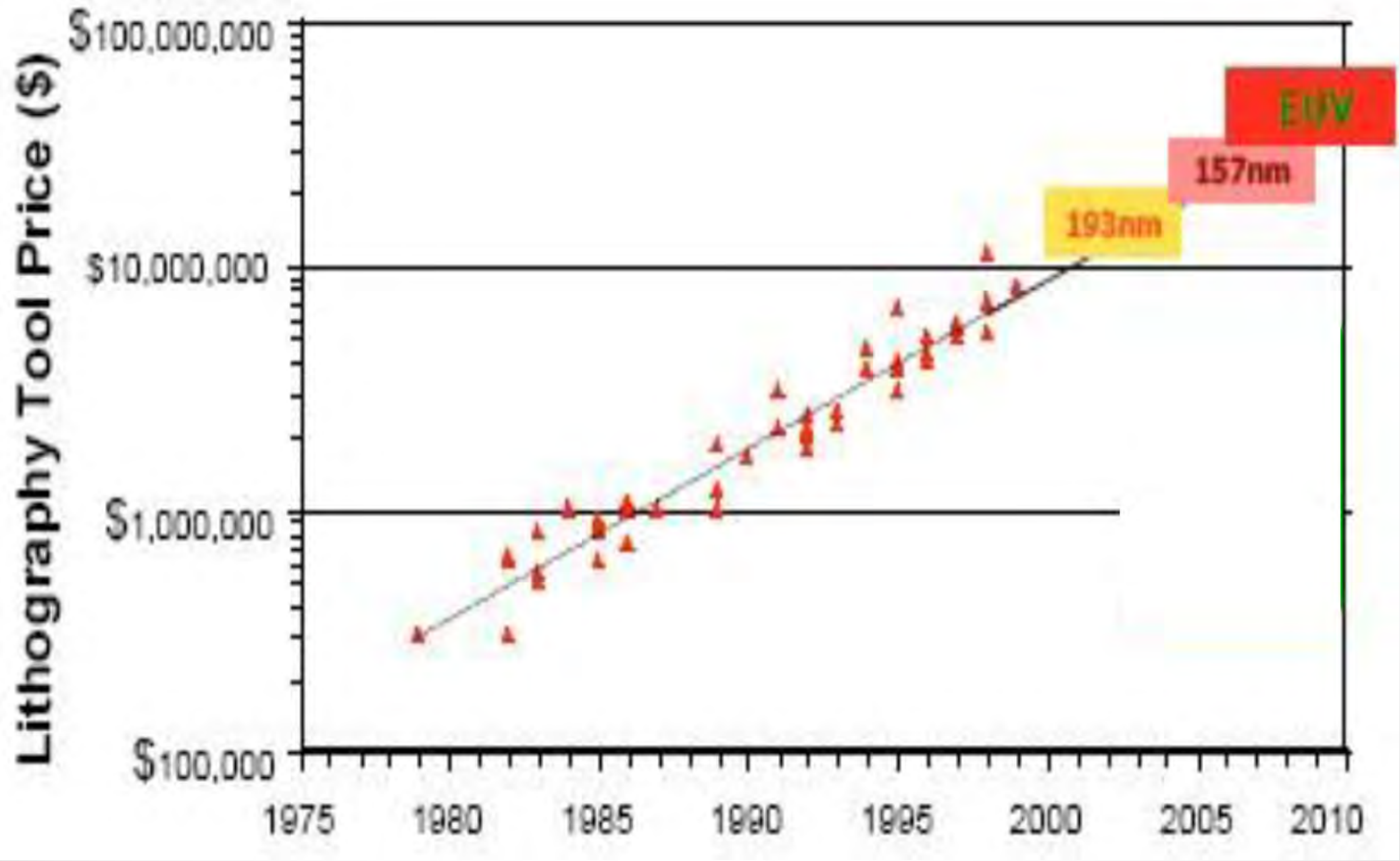

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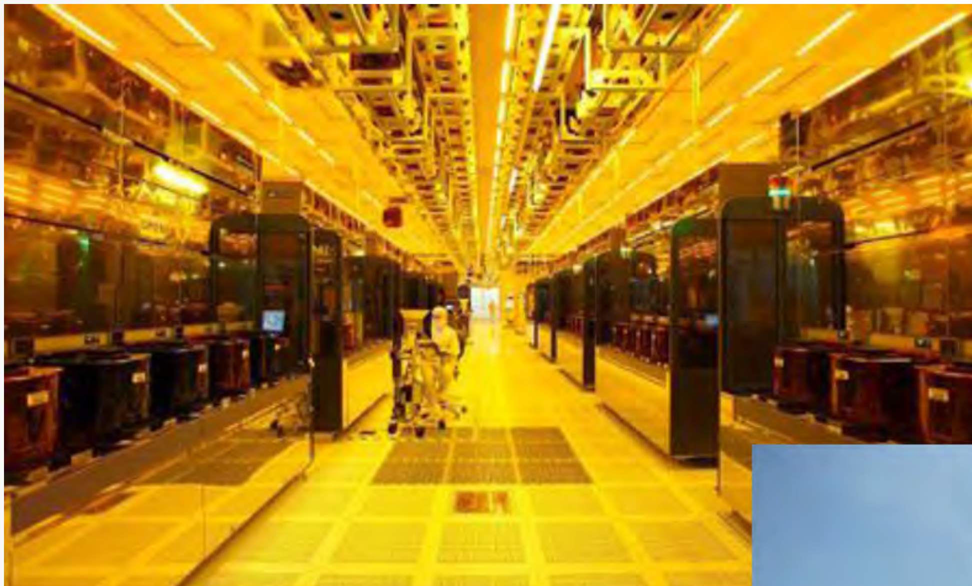
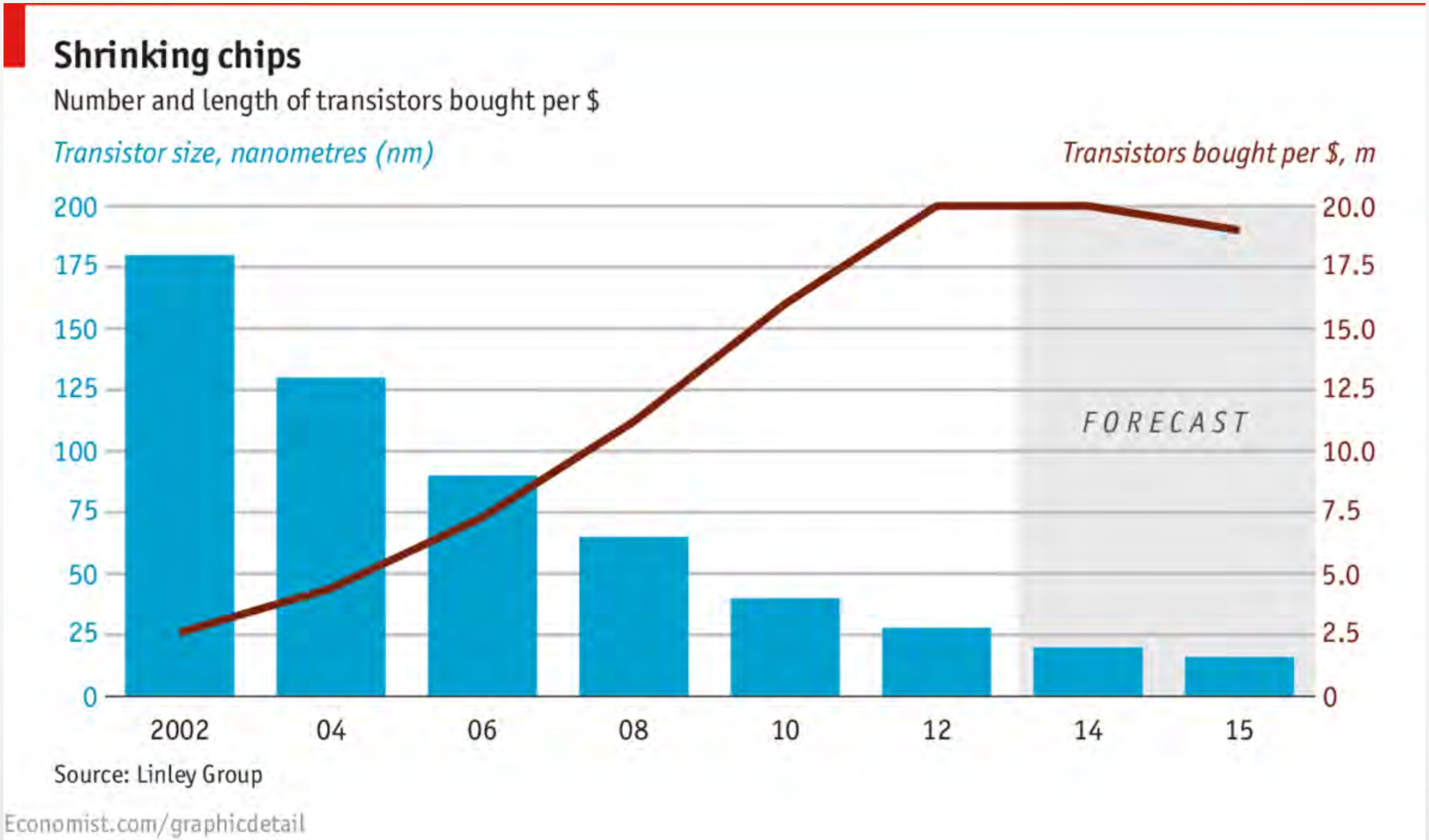


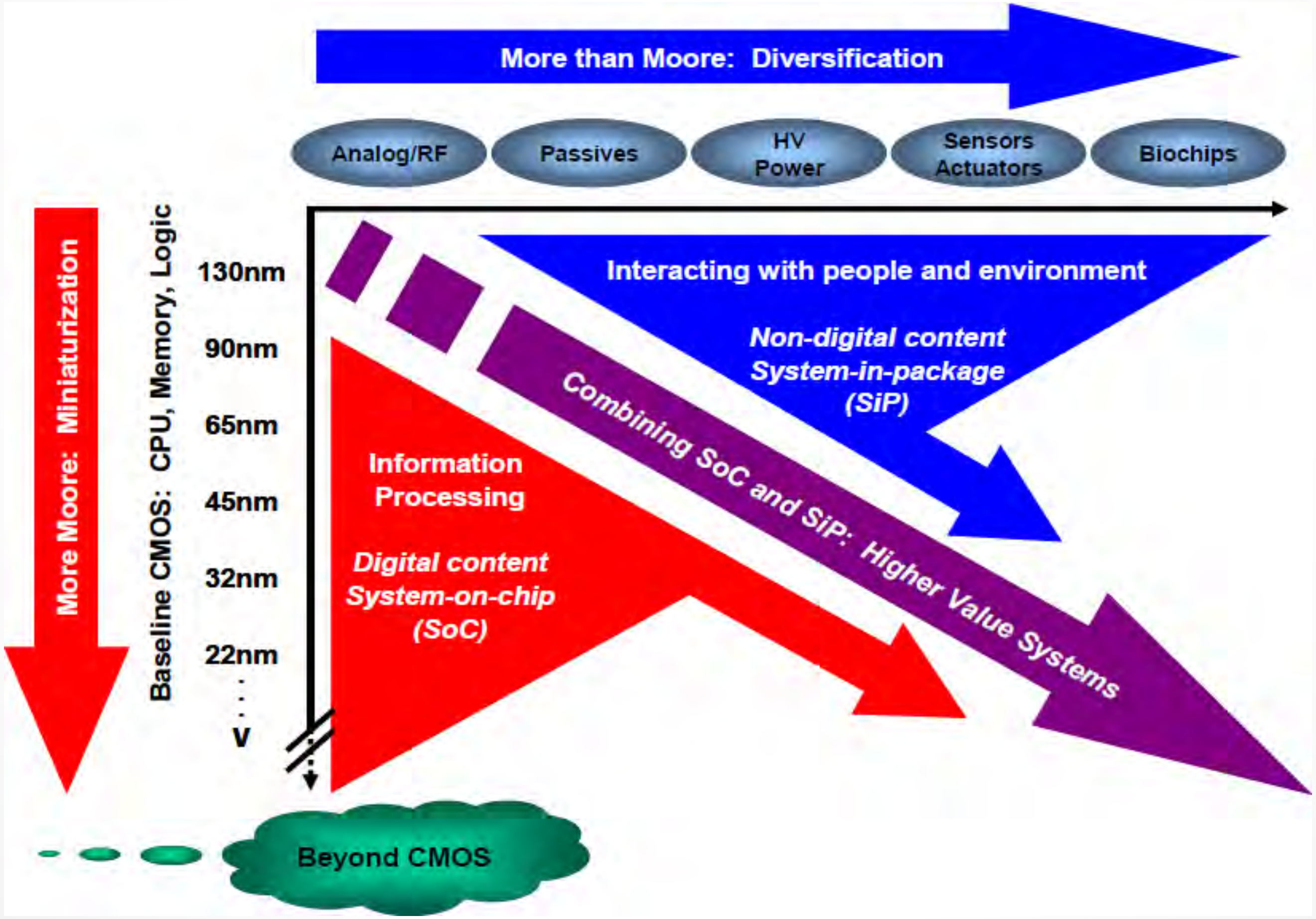
TSMC's Fab 12 Phase 4: 9.3 G$

Global Foundries new fab: 6-8 G$

Ultimately Fueled and Limited by Economics



More Than Moore…



Academic SW vs SW Engineering

- Training for Research vs Training by Research

  → **Employability**
- Numerical simulations / Complex data analysis
  - Growing importance in the material science arena
  - Opportunity for acquiring “dual use” skills / knowledges / methodologies:
    - statistical physics → financial product/market modelling
    - HPC, software engineering, project management…
- I am spending a fair amount of my PhD writing/using code, great! Nevertheless, am I likely to be considered a good candidate for a (broadly speaking) software related job if I am looking for such a position in the industry?
- Some prerequisites…”state of the art” infrastructure / technologies / methodologies
  - Does it make any sense for a research organization to still rely on in-house computing hardware resources while cloud computing is out there?
  - Why am I still dealing with FORTRAN in 2016?
  - Documentation, version control, regression testing…you are kidding me, right?

The Startup Universe…

- Start-ups opportunities and risks : employees / founders
  - SOFER / Quinta / Vega Vista / Grandis / In Silicio
- The start-ups role(s)/position(s) in the global ecosystem of innovation
  - B to C vs B to B
- The fundamentals:
  - Innovation / **Business Model** / Market Opportunity (Vega Vista vs Grandis)
  - Intellectual property (SOFER vs Grandis vs In Silicio)
  - The team (SOFER vs In Silicio)
  - Innovation ecosystem : Silicon Valley vs Europe
  - "Big players" : customers / partners / share holders ? (Quinta / Grandis - EDA)
  - Time to market / early revenues / burning rate (Vega Vista vs In Silicio)
  - Funding / VCs or not VCs ?
  - Exit strategy
- The personal equation
  - Optimal timing : professional vs personal
  - Rewards and toll